Conceptual Article

Mathematics teacher education in South Africa: A research agenda focused on the mathematical work of teaching across diverse contexts

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Abstract

Mathematics teacher education in South Africa faces unique challenges shaped by the country's social, cultural, linguistic, and economic diversity. Preparing teachers who can effectively engage with learners across such varied contexts requires a research agenda that foregrounds the mathematical work of teaching (MWT)—the specialized content knowledge, pedagogical reasoning, and classroom practices that enable effective mathematics instruction. This paper outlines a research agenda that emphasizes three key areas: (1) understanding how teachers engage with mathematical concepts and learners' reasoning in multilingual and resource-constrained environments, (2) exploring the relationship between teachers' professional knowledge and their instructional practices, and (3) examining the institutional and policy frameworks that shape teacher preparation and continuing professional development. The agenda calls for empirical studies, context-sensitive methodologies, and collaborative approaches that integrate teacher educators, researchers, and practitioners. By situating the mathematical work of teaching within South Africa's diverse educational contexts, this research agenda seeks to inform policies and practices that strengthen teacher education, improve mathematics learning outcomes, and contribute to equity and quality in education.

Keywords: *Mathematics teacher education; South Africa; mathematical work of teaching; pedagogy; teacher professional development; educational diversity; multilingual classrooms; equity in education.*

INTRODUCTION

This paper reflects on aspects of mathematics .teacher education in South Africa, with a focus on "the ·mathematical work of teaching". This brings the following questions to our minds.

1. What do mathematics teachers need to know to be able to do, to teach mathematics well?
2. How do the mathematical work teachers do. differ across diverse contexts of teaching?
3. Can we arrive at a research agenda in support of all this?

The underlying theoretical assumption behind such a research agenda is that mathematical work is situated. This assumption is borne out by empirical studies of mathematics used in various workplaces where there is a specificity to how mathematics. is attuned to the needs and demands of varying cultural practices (Noss, 2002; Noss, Hoyles & Pozzi, 2001). Similarly, it is arguable that there is specificity to the mathematical demands of teaching. The difference, of course, is that teachers are trying to teach mathematics. This makes the mathematical demands of their work different from nurses, say, who use mathematics in the course of their nursing. Their work is to nurse others to health, and so not mathematical in its intentions and outcomes. This difference aside, there is growing support for the notion that there is specificity to the way teachers need to hold and use mathematics in order ·to teach mathematics - and that this way of knowing and using mathematics differs .from the way mathematician hold and use mathematics (Ball & Bass, 2000). As this knowledge has a practice base, more focused research on mathematics teaching is required. Otherwise it will remain under-described and not well understood. This has significant implications for mathematics teacher education: it raises questions on the mathematical education of teachers, whether it gears itself to these ways of knowing and using mathematics.

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The resonance of a notion of the mathematical work of teaching being situated has practical and local roots in my work over many years in diverse classrooms in South Africa. There are diverse demands on teachers and teaching across ranging contexts, particularly those constituted by deep inequality and, as in now increasingly common elsewhere, by multilingualism. I have argued elsewhere (Adler, 2001) that there are context- related dilemmas of teaching in multilingual mathematics classrooms. This earlier research reveals that all teaching is dilemma-filled. However, South African mathematics teachers manage particular language-related dilemmas that are at once a function of both their personal biography and the varying contexts of their work. What that research did not explicitly foreground, however, was the mathematical work teachers did to manage these dilemmas. As is discussed later in this paper, secondary analysis of this data could reveal whether and how the mathematical work of teaching across contexts is indeed a fruitful field of research.

Issues of access and equity in education are both global and local. More and more, countries across the world are dealing with the economic and electronic divide, either Jqcally qr globally or both. And in many developed contexts, urban·schooling has come to be defined by economic and linguistic inequality. It follows that one methodological implication of a situated notion of mathematical work of teaching is that this critical field needs to be informed by research that is carried out in diverse classrooms. Simply put - the empirical sites for understanding the mathematical work of teaching matter.

This paper describes the circumstances (research-based and practical) that have led to this focal point in my research. The conditions in mathematics teaching and teacher education in South Africa described in this paper leads to the questions: Is. what teachers need to know and be able to do mathematically to teach in such conditions obvious? Is this knowledge in and for the practice of teaching well described and understood? This paper also looks at research that has been done, as this provides some of the rationale for the knowledge-for-teaching agenda, and also the basis on which such research can build. Some of this research is discussed later in this paper, with focus on the mathematical work teachers appear to be doing.

CONDITIONS ON THE GROUND IN SOUTH AFRICA

Three questions frame the discussion of conditions on the ground in South Africa. Who are going to be, and who currently are, mathematics teachers in South Africa? For the purposes of this paper, and for more focused research these questions will have a Senior Phase (Grades 7 - 9) teacher in mind. What mathematics is selected into the Senior Phase curriculum i.e. what are teachers required to teach? Where are teachers going to teach?

Who are / going to be mathematics teachers in SA?

Currently, few graduates in mathematics are choosing to enter teaching in South Africa. Numbers in our Post Graduate Certificate in Education (PGCE). the usual route for secondary teacher qualification, have diminished dramatically in the past ten years. Shortages of suitably qualified secondary mathematics teachers in South Africa have reached critical propo1iions. Some might 'blame' this situation on the turmoil in post-apartheid education, and demoralization across the profession. However. this phenomenon is not peculiar to South Africa.

A four year undergraduate teacher education B Ed degree is now in place in the country, and, in my own institution, we have, relatively speaking, a reasonable intake of students. To date, three cohorts have graduated and these new teachers are qualified to teach mathematics across .secondary grades. The issue we face and deal with in the conceptualization and teaching of this undergraduate program is that these students, typically, did not perform particularly well in mathematics in .school. If they had, it is more likely they would have entered the Science Faculty. If they are to emerge from their studies with strong mathematical identities, these need to be produced and nurtured through their mathematics courses.

At the same time, the majority of black secondary teachers trained under apartheid only had access to a three year College of Education diploma. It is beyond the scope of this paper to explain just how poor, much of the quality of this training was (welsch, 2002). Hence many secondary mathematics teachers currently in service have not had adequate opportunity to learn further mathematics. Here too, mathematics teacher education faces the challenge of working on intervention programs where in-service teachers can develop their mathematical knowledge and mathematical identities. What mathematics should be in such programmes? Where and how should these be taught?

The critical point here is that in both pre- and in-service mathematics teacher education programs, mathematical know-how and dispositions need to be produced, and in ways that will enable teachers to. project strong mathematical identities in their teaching. This is a considerable challenge, and contrary to assumptions that underpin secondary mathematics teacher education: that prospective secondary teachers already have a mathematical disposition and considerable mathematical competence that now needs to be tuned to the needs of teaching.

What mathematics are Senior Phase teachers required to teach?

Elsewhere, and drawing on Hargreaves (2001) and Elliott (2001), I have described the paradoxes facing teaching and teacher education in general (Adler, 2002). Teachers are being expected to meet multiple and competing needs simultaneously: for excellence and equity, for alleviating social ills, and performing well in competitive assessments. The list goes on. Graven (2002) brings some of these paradoxes to light for mathematics. In a detailed analysis of new Norms and Standards for Teacher· Education in South Africa, and the Revised National Curriculum Statement for Mathematics, Graven shows the multiple and competing roles and identities implicit for mathematics teaching in South Africa. Senior phase mathematics teachers are expected to induct learners into mathematical thinking (an investigative and problem-solving approach to mathematics is advocated through much of the policy documentation). At the same time, teachers are to appreciate how mathematics is and. can be used in real-life problem solving (that is, an . applied orientation to mathematics is simultaneously advocated). Moreover, given the history of South Africa, there is now an explicit demand for all education to tackle issues of democracy and human rights, and so built into the mathematics curriculum is the expectation that teachers will induct learners into a critical approach to the uses and abuses of mathematics, and to the skills needed for critical and participatory citizenship. All of these are to be bolstered by levels of procedural and computational fluency. These are what ·we could describe as a wide range of mathematical practices, and they are embedded in new and old topics in the curriculum (e.g. data handling - statistics and probability; transformation geometry are new curriculum topics). Neither these topics, nor an explicit focus• on mathematical practices are the typical fare· of mathematics courses in teacher preparation and development programs.

Where are mathematics teachers teaching?

Much has been written about inequality of education that was produced by apartheid education.

We have, elsewhere, called the English Language Infrastructure in a school (Adler, 2001; Setati, Adler, Reed & Bapoo, 2002). Language-in- education policy advocates additive multilingualism. Yet, English remains the language of power, and so the preferred language of learning and teaching (LoLT) (Adler, 2001; Setati, 2002). Urban and non-urban schools in

South Africa differ substantively in the extent to which English language is heard and used in and around the school.. In many non-urban areas, 'poverty prevails. There are few resources, including written texts. In addition, the dominant language in the region is the one in use outside of schooling. In all schools, teachers and learners aspire to English language fluency and so mathematics comes to be taught in and through English. The demands on teachers in non-urban contexts, are enormous as they are teaching in what can be described as Foreign Language Learning Environments (Setati .et al, 2002).

What is the mathematical work of teaching across such contexts? What are the linguistic and mathematical demands on teaching when the LoLT at the same time, is an object of study? What do mathematics teachers need to know and be able to do mathematically to teach this curriculum in these conditions? Do we know how to answer these questions effectively? What have we learned from previous research?

WHAT HAVE WE LEARNED FROM PREVIOUS RESEARCH?

In the concluding chapter on a report of research on teachers' take-up from a formalized in-service program, Adler, Slonimsky & Reed (2002) posit that a central task for teacher research and development in South Africa is to better grasp what we coined "conceptual-knowledge-for-teaching." We arrived at this through a three-year, in-depth study of mathematics, science and English language teachers who participated in a formalized HY-service teacher development programme. Both in the programme and in the research, what remained elusive yet central to all explanations of take-up, be it in relation to use of resources, mediation or reflection on practice, was the ways in which teachers' struggled to elaborate the subject purposes of their work. We argued that a simplistic and typical response to this (e.g. Taylor & Vinjevold, 1999) is. that teachers do not know their subject (mathematics) well enough, and therefore need to do more· courses in mathematics. The simplicity of this interpretation leads to the kinds of formalised in-service programmes we have seen mushroom across universities in South Africa in the past few years. Teachers who were subjected to the inequities of apartheid teacher education (Welsch, 2002) are now provided upgrading possibilities - where they are being offered opportunities to learn 'more' maths, and .perhaps some mathematics education.

This response, however well-intended, fails to grasp the specificity and complexity of subject knowledge for teaching, and reinforces the suggestion made earlier, that this kind of knowledge is under-described. How does knowledge of andabout mathematics, for example, come to be used effectively in teaching? The problem here is not simply one of different pieces or kinds of mathematics teachers need to know, but critically one. of how it needs to be used to enable others to come to know mathematics. In the mid-1980s, and what can be described as a critical moment in the educational field of knowledge about the practice of teaching, Lee Shulman posited the notion of Pedagogic Content Knowledge (PCK) (Shulman, 1986, 1987). He pointed to the complex nature of knowledge-in-use in and for teaching, and the centrality of the integration of disciplinary or subject knowledge with knowledge. about teaching and learning for successful teaching. Ball & Bass (op cit) have done a great deal to• elaborate the nature of this mathematical work through their in depth study of an elementary teacher's work in a Grade 3 classroom over a full school year, and more recently through studies across a range of elementary classrooms in the United States (Ball et al, 2008; Hill et al. 2008). Like them, I posit that we do not know enough about this mathematical work that teachers do, and further that as this is practice_-based knowledge, we are faced with an empirical question. Just as Noss & Hoyles studied nurses' uses of mathematics in their day to day nursing work, so we need to study more systematically the what and how of mathematics in use in teaching.

As mentioned, Ball and her research colleagues have already contributed to such a research agenda. Indeed there are others researching subject knowledge for teaching with a specific focus on mathematics (e.g. Even, 1990; Kennedy, 1997; Ma, 1999). and these include studies at the secondary level. My own work in South Africa in the past few years has focused on mathematics for teaching, with particular interest in what is being offered in. teacher education {Adler & Davis, 2007; Davis, Adler and Parker, 2007; Adler & Huillet, 2008). Work in this field is thus already underway. What is its value in the South African context? Is there more that could or needs to be learned?

Research on teaching and learning mathematics in multilingual classrooms

Research on teachers' knowledge of the practices in urban secondary multilingual mathematics classrooms in South Africa (Adler, 2001) posits three dilemmas of teaching that describe such knowledge: dilemmas of code-switching (of enabling meaning through use of learners main language vs enabling access to English as the language of instruction, and the language of advancement); dilemmas of mediation (of valuing diverse learner productions vs production mathematical communicative competence); and dilemmas of transparency (of managing implicit and explicit mathematical language practices). The overarching argument is that. firstly, these dilemmas are at once personal and contextual, a function of the teacher's biography and the context in which thej' teach: and secondly that teachers manage these dilemmas in their day-to-day practice, making professional judgements as to how they work with many languages and diverse linguistic competencies present in their classrooms; Standing back from these dilemmas and the earlier, a question I now ask, (this was not in focus during that study) is: What mathematical moves do teachers make, or need to know how to make. in these moments? Is the mathematics teachers come to use attuned in any particular way to these diverse contextual conditions?

Setatl & Adler (2001) and Setati et al (2002) have described the complex journey that is or needs to be traveled in mathematics classrooms, from informal talk in learners' main language to mathematical writing in English, and the challenges for teachers in navigating this terrain. These challenges are at once a function of context, and more pertinently here, a function of working across multiple languages and discourses in the mathematics classroom. In the latter study of teachers· take-up from a formal in-service programme (Setati et al, 2002) we have shown how the English language infrastructure across urban and rural schools matters, and how teachers' navigation of the journey was largely incomplete or abbreviated. Their take- up from the programme in relation to language as a resource for learning and teaching resulted in a dominant practice of learners being afforded opportunity to use their main languages as a social thinking tool, and in informal talk as they began work on a mathematical task. The moves from there to mathematical talk and writing in English and mathematical English more particularly. were either absent (learner activity remained at that level} or abbreviated {with a radical jump by the teacher to .formalized mathematics in English). In the study we illustrated further that language• practices, particularly code-switching, differ across levels {elementary and secondary classrooms); across school subjects (teaching and learning English a language vs teaching and learning Mathematics of Science). The range of dimensions of diversity across contexts matters in the teaching and learning of mathematics.

And so here too the question arises as to whether there ·are specific mathematical entailments of teaching across diverse linguistic contexts. My work to date has not had this as an explicit focus. (How) do diverse contexts matter for the mathematical work that teachers do and need to do in order to teach mathematics well? Do they need to think about and work with mathematics in any specific ways so that they can enable their diverse learners, in diverse and often difficult conditions to learn? In simple terms, research· in teacher education, and on the. teaching and learning of mathematics in and across diverse (including multilingual) classrooms adds weight to the potential significance of the question of the mathematical work of teaching - context does matter. and it is and open and empirical question as to how this functions to· produce particular mathematical demands on teachers. It is thus important that the current work on subject knowledge for teaching and pedagogic content knowledge is carried out in diverse classroom contexts. and ther1 too with appropriate theoretical tools that will enable a gaze that holds the context and mathematics in their inter-relation in focus.

A RESEARCH AGENDA

In this paper I have built an argument for specificity to the mathematical work of teaching, and further that this work might have specific entailments across diverse contexts of practice. These entailments are practice-based, and so require a study of mathematics in use in teaching across diverse contexts of practice. An identification and description of this work is what is needed, and embedded here is the practical problem of the mathematical preparation of teachers. And so a research agenda follows. The underlying assumption is that such mathematical foci could then be included in the mathematics preparation and ongoing professional development of teachers, and that this will make a difference to their being able to teach mathematics well. Of course, effective and appropriate mathematics in teacher education remains a further empirical question.

The beginning of this work is underway, fuelled by a brief and partial secondary analysis of some of the data collected in my first study on. teachers' knowledge of their practices in multilingual classrooms (Adler, 2001). I thus turn in this final section of the paper to discuss two teaching episodes in the earlier study, and the mathematical work the teachers appeared to have done, or needed to do to construct and mediate the tasks they presented their learners .

❖ Working across discourses

In a lesson preparing the ground for Grade 11 learners to study linear programming, the teacher developed a table on the chalk board with learners which focused their attention on two particularly troublesome phrases in mathematical English that learners would need to use in linear programming problems: 'at most' and 'at least'. A detailed description of this lesson episode and its context is provided in Adler (2001) and not repeated here. My attention instead is on uncovering the mathematical work entailed for. the teacher in preparing and teaching this activity.

The learners in this class were predominantly Tswana-speaking. and with varying degrees of fluency in ·English (and so too Mathematical English). Consequently, the teacher focused their attention on 'at most' and 'at least' in a way that had them relate these phrases firstly to the related mathematical phrases 'not more than' and 'not less than'. (negations): secondly to everyday contexts where these terms might be used; and then thirdly to the symbolic forms such expressions would take. A table was constructed in interaction with learners that related the Mathematical English to everyday English and to a symbolic expression as captured below.

Mathematical words	Settings	Mathematical symbols
Not more than	You can spend not more than R50	$\leq$
Not less than/ at least	There were at least 10 people at the meeting-	$\geq$
At most	You can spend at most RSO	$\leq$

My purpose here is not to discuss how this table came to be used, or whether its construction is an appropriate and productive way to deal with these language demands in linear programming. It is rather, at this departure point in a research process, to ask: what mathematical work is in play for the teacher as she works with a diverse class of learners to access the mathematical practice of translation between verbal and symbolic mathematical expressions, and between these and everyday discourses, and all in English.

What is the range of mathematical practices entailed in the task of relating and tabulating everyday phrases, mathematical phrases and mathematical signs and symbols?

Firstly, translation across discourses is obvious. In addition, 'ordering' is critical in this mathematical work. Translating the expression 'not more than R50' into a mathematical expression in symbolic form (which is what linear programming tasks require) is not only a matter of identifying an appropriate sign or symbol (£), but critically on how it is ordered as it is connected with relevant other signs and symbols - here 'x' and 'R50'.

Ordering is in play even when translating ordinary. English to mathematical English. We know too well the difficulties with translating "there are twice as many chairs as tables" into a mathematical statement. I have often heard African speakers of English ordering numbers where the larger number is placed first e.g, "I need 5 or 4 of those" - a sign that the spoken ordering of numbers in some African languages differs from such ordering in English and Mathematical English. Order matters in translation, be .it from one language to another across discourses, and from words to. symbols in mathematics. And it matters in specific ways in mathematics. So what then is entailed in teaching ordering in mathematical translations, an aspect of mathematical work that was not actually in focus in the lesson from which this episode is drawn, nor in the analysis of the lesson in my earlier research?

Just as 'ordering' matters in the mathematical work of teaching. so do metaphors for teaching. This latter might be better categorized as pedagogic mathematical knowledge for teaching. In the above episode, the teachers· choice of contexts/settings to illuminate these notions is interesting, and deeply contextual. At that time in South Africa, secondary school learners were caught up with the politics of the demise of apartheid, and spent much of their time during school in political meetings. Metaphors matter, as they carry meanings in everyday discursive practices that can enable or obscure the mathematical notion the teacher is hoping to illuminate. Walkerdine's work (1988} as discussed in Adler (2001) is illuminating here.

This discussion on key mathematical practices in the kind of task exemplified above provides an additional lens on aspects of the language of mathematics that are well known. It has also brought out some inter- relation between the mathematical work of teaching in general, and an aspect of how this might take on specific significance in linguistically diverse settings. It was a re-examination of this earlier work that suggests that examining mathematics in use in teaching across classroom contexts would be productive.

❖ Designing and mediating productive tasks

I now turn to a second episode, also described in detail in Adler (2001), this time in a Grade 8 classroom where the teacher was English-speaking, but most learners had languages other. than English as their main language. Here the teacher was focused more on learners talking to learn, and learning to reason mathematically. As part of a sequence of tasks related to properties of triangles, the teacher gave the activity in the box below to her Grade 8 classes. If any of these is impossible, explain why. otherwise draw it.

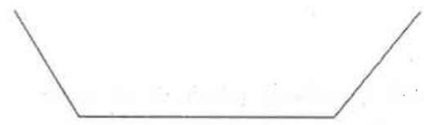
- Draw a triangle with 3 acute angles.
- Draw a triangle with 1 obtuse angle.
- Draw a triangle with 2 obtuse angles.
- Draw a triangle with l reflex angle.
- Draw a triangle with 1 right angle.

The task itself evidences different elements of important mathematical work entailed in teaching learners to reason mathematically. Firstly, this is not a 'typical' task on the properties of triangles. A more usual task would be to have learners recognize different types of triangles, defined by various sized angles in the triangle.·What the teacher has done here is recast a 'recognition' task into a 'reasoning' task. She has constn1cted the task so that learners are required to reason if they are to proceed with the task. In so doing, the teacher sets up conditions for producing mathematical reasoning in the lesson and related proficiencies in her learners.

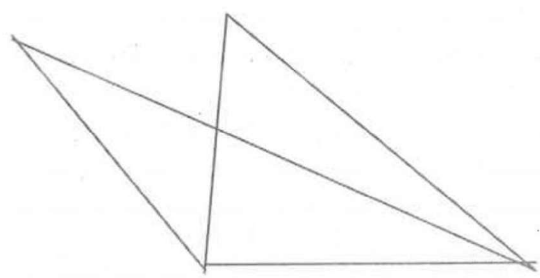
In constructing the task so that learners need to respond whether or not particular angle combinations are 'impossible' in forming a triangle, the teacher expects a proof-like justification, an argument or explanation that will hold··in all cases (for otherwise it will not be impossible). What is entailed here, mathematically? The teacher would need to think about the mathematical resources available to this classroom community with which they could construct a general answer (one that holds in all cases). The learners do know and have worked with angle sum in a triangle. What e1se might come into play as learners go about this task?

In this particular classroom, students worked on their responses in pairs. The teacher moved across the classroom, asking questions like: Explain to me what you have drawn/written here? Are you sure? Will this always be the case? I foreground here student responses to the item: Draw a triangle with two obtuse angles. On this part of the task, there was a range of learner responses - indicative of ci further skill embedded in this task. It is designed in a way that diverse learner responses are possible and enabled.

- *Some said: It is impossible to draw a triangle with two obtuse angles, because you will get a quadrilateral. And they drew:*



- Others reasoned as follows: an obtuse angle is more than 90 degrees and so two obtuse angles gives .you more than 180 degrees, and so you won't have a triangle because the angles must add up to 180 degrees
- Joe and his partner reasoned in this way: If you start with an angle say of 89 degrees, and you "stretch it", the other angles will shrink and so you won't be able to get another obtuse angle. They drew:



Now it is the teacher's task to mediate across these responses, and enable her learners to reason whether each of these responses is a general one, one that holds in all cases. The interesting interactions that follow in the class are described and problematised in Adler (2001) and will not be focused on here. In the many contexts where I have presented the study and this particular episode, much discussion is generated both in relation to the mathematical status of the responses, and their levels of generality, as well as simultaneous arguments as to what can be expected of learners at a grade 8 level. What constitutes a generalized answer at this level? Are all three responses equally general? Is Joe's response a. generalized one?

These are mathematical questions, and the kind of mathematical work this teacher did on the spot as she worked to value and validate what the learners produced. The point here is that this kind of mathematical work i.e; working to provoke, recognize and then mediate notions of proof and different kinds of justification is critical to effective teaching of 'big ideas' (like proof) in mathematics. Yet this kind of mathematics is rarely the focus of attention in the· mathematical preparation of teachers.

IN CONCLUSION

In this paper I have presented a description of how I have come to a particular research agenda focused on the mathematical work of teaching, and its possible entailments across diverse classroom contexts; My driving motivation is: If we know more about 'what' and 'how' mathematics is used in and for teaching across contexts, we will then be able to grapple with whether, how and where these practices a.re teachable, and then too who (what expertise) is required for this teaching.

In addition to motivating this agenda, I turned to some· secondary analysis of data from an earlier project to explore the value of studying the mathematical work of teaching across contexts. Looking inside teachers' work in two different multilingual mathematics classrooms in South Africa, it does appear as if context matters in unearthing the specificity of teachers' mathematical work. The elements of the mathematical work of teaching identified in this paper viz. translation across· discourses,. ordering in mathematical representation, recasting tasks, valuing diverse ·levels of justification, are typically not in focus in mathematics courses taken by prospective teachers in their undergraduate mathematics study in South Africa, and because they are mathematical in nature, they do not appear to be in focus in 'methods' courses either. There is thus much work to do in mathematics teacher education, both practically and in terms of research.

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